

Single Point Precision and Bias Graphics
For Gaseous Criteria Pollutants

Companion Document

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1 Background

In order to provide decision makers with data of adequate quality, OAQPS is using the Data Quality Objective (DQO) process to determine our data quality needs for our ambient air criteria pollutants. There are some data quality indicators, such as precision, bias, and completeness that directly effect the attainment of the DQOs . These variables need to be in certain acceptable ranges (called measurement quality objectives) in order for us to make decisions (like comparison with the NAAQS) with specified levels of confidence. 40 CFR Part 58 Appendix A provides the minimum requirements for the collection and reporting of data to assess the data quality indicators of precision, bias, and completeness. On an annual basis, the Air Measurements and Quality Group (AMQG) develop summary reports on these data quality indicators.

OAQPS is in the process of revising the current statistics described 40 CFR Part 58. As was written in the 1983 document entitled “*Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58 Appendices A and B*”, “ the P&A statistics represented a compromise between (a) theoretical statistical exactness, and (b) simplicity and uniformity in computational procedures”. The current CFR Appendix A statistics (with the exception of PM_{2.5}) aggregate precision and bias into one statistic which make it difficult to use for input to the DQO process.

OAQPS is revising 40 CFR Part 58 Appendix A in order to base the precision and bias measurement quality objectives on confidence intervals at the site level of data aggregation. Since the criteria pollutant data are used for very important decisions (comparison to the NAAQS) it is felt that providing precision and bias estimates at upper confidence limits provides a higher probability of making appropriate decisions. This statistic provides a conservative approach to measuring precision and bias. A document describing these statistics is available on AMTIC.
(<http://www.epa.gov/ttn/amtic/parslist.html>)

Estimates of both bias and precision for the four automated gaseous methods (CO, NO₂, O₃, and SO₂) are derived from the bi-weekly one-point QC (formerly called precision) checks. Since every site performs the QC checks at an acceptable frequency, there is enough information to assess and control data quality at the site level.

In 2005, OAQPS developed a new report in AQS (AMP255 – P/A Quality Indicator Summary Report) that summarized precision, bias, and completeness of the required QC data for each criteria pollutant. The data tables may be generated at any time within the AQS application using the standard report. Earlier reports also generated this data graphically which monitoring organizations found very useful. Since AQS presently does not have this capability, AMQG is providing these graphs annually as an addendum to the summary tables.

This document defines the elements displayed in the corresponding box and whisker graphics as well as base assumptions of the data contained within the AMP255 report.

2 Report Description

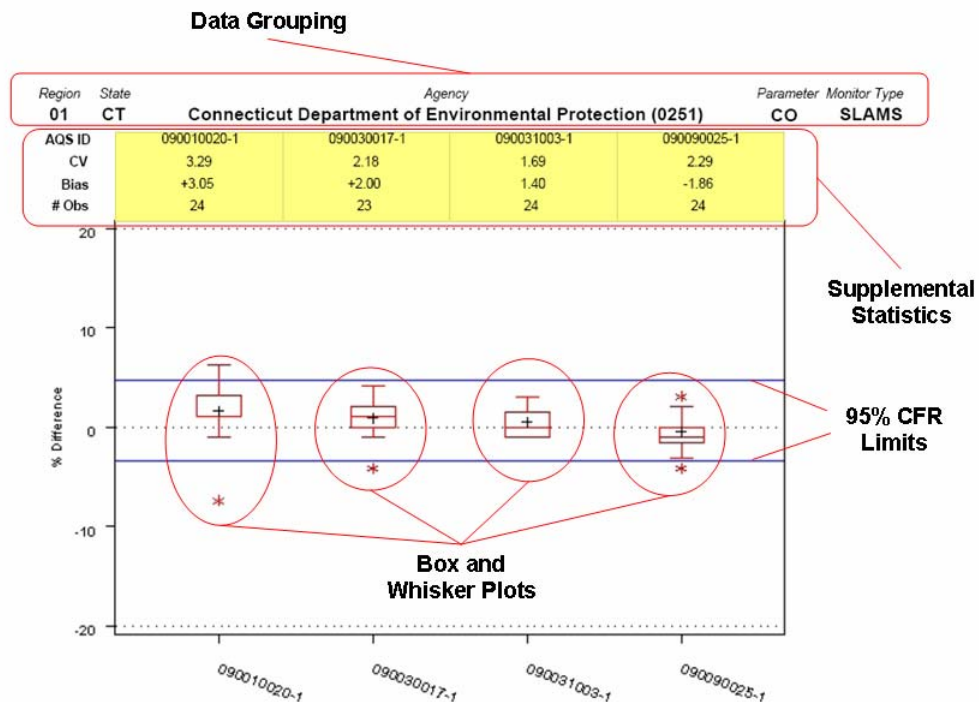
2.1 Components of the Graphs

2.1.1 Overview

Each graph presented in the *2004 Single Point Precision and Bias Graphics for Criteria Pollutants* is comprised of four parts. Each of these parts are discussed in the following sections. The four parts of each graph are as follows:

- Data Grouping
- Supplemental Statistics
- Box and Whisker Plots
- 95% CFR Confidence Limits

Figure 1 illustrates how these different components appear within each graph.



Precision and Bias Report Sample Page

Figure 1 - Precision and Bias Report Sample Page

A given plot will display up to nine box plots per graph and a maximum of two plots will appear on a given page. Therefore, if an agency has more than 18 monitors measuring the same pollutant for the same monitor type category, the graphs will appear on multiple pages.

2.1.2 Data Grouping

Each page of the report displays the results for a particular data grouping. A “data grouping” is defined by unique combinations of [Region](#) – [State](#) – [Agency](#) – [Pollutant](#) - [Monitor Type Classification](#) combinations. The data grouping is located at the top of each page. The plots are sorted in the following order:

1. Region
2. State Abbreviation
3. Agency Code
4. Parameter (CO, NO₂, O₃, SO₂)
5. Monitor Type Classification (OTHER, SLAMS)

2.1.3 Supplemental Statistics

In addition to the statistics represented in the graph, the following information and statistics are displayed for each monitor within each data grouping:

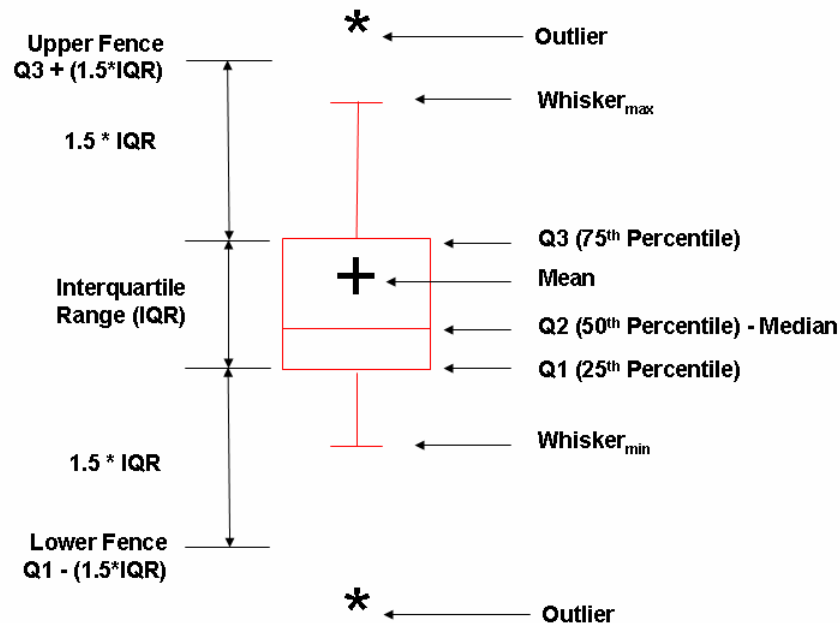
- [AQS ID](#) – The plots are sorted by the AQS ID in ascending order.
- [Bias](#) Upper Bound
- [CV](#) Upper Bound
- [# Obs](#) - Number of Samples contained within the set

2.1.4 Box and Whisker Plots

A “Box and Whisker Plot” is created for each monitor within a reporting organization measuring a gaseous criteria pollutant (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide). A single box plot is based on the percent relative error statistics from the one-point precision checks for a single monitoring site measuring a pollutant conducted within the effective [time period](#) in 2004. Multiple box plots are displayed within a [data grouping](#). A box plot displays the following statistics:

- [Q3 \(75th Percentile\)](#)
- [Q2 \(50th Percentile\) - Median](#)
- [Q1 \(25th Percentile\)](#)
- [Arithmetic Mean](#)
- [Whisker_{min}](#) & [Whisker_{max}](#) The lowest and highest values respectively that are found within the upper and lower fence. The upper and lower fences are defined as values between $Q1 - (1.5 * IQR)$ and $Q3 + (1.5 * IQR)$, where “IQR” = $Q3 - Q1$.
- [Outliers](#): All values that fall outside (above or below) the upper and lower fences.

The statistics are represented according to *Figure 2*.



Components of a Schematic Box and Whisker Plot

Figure 2 - Components of a Schematic Box and Whisker Plot

2.1.5 95% CFR Limits

The following statistics are calculated for all Pollutant - monitor type category - monitors within the reporting organization:

- [95% CFR Upper Confidence Limit](#)
- [95% CFR Lower Confidence Limit](#)

The 95% Confidence Limits are displayed as blue lines with the box and whisker plots.

2.2 Definitions for Each of the Displayed Items

2.2.1 Data Grouping

The data grouping is a unique combination of a Region, State, Agency, Pollutant, and Monitor Type Classification. The data grouping for each box plot appears at the top of each page.

2.2.2 Time Period

The time period for a given monitor is defined as either 1 or 2 (below):

1. The monitoring season defined for the monitor, if it exists. Generally, this only applies to ozone monitors.
2. January 1, 2004 – December 31, 2004 if no monitoring season is defined.

2.2.3 Region

The USEPA Region code associated with a given monitoring site.

2.2.4 State

A 2-character postal abbreviation is used to identify a state in which the monitoring site is located.

2.2.5 Agency

This is the description for the reporting organization along with its corresponding AQS agency code. The reporting organization is the agency responsible for the quality assurance information submitted to AQS.

2.2.6 Pollutant

This is an abbreviation for the pollutant under consideration. The following abbreviations will be used for display in the report:

Abbreviation	AQS Parameter Code	Pollutant Name
CO	42101	Carbon Monoxide
SO ₂	42401	Sulfur Dioxide
NO ₂	42602	Nitrogen Dioxide
O ₃	44201	Ozone

2.2.7 Monitor Type Classifications

A monitor within a site will fall into one of two monitor type classifications:

- a. If a monitor is defined as a NAMS, PAMS, SLAMS and / or UNOFFICIAL PAMS monitor type within the report period, it is classified as “SLAMS”.
- b. If none of the condition of “a)” exist, the monitor is classified as an “OTHER” monitor type.

2.2.8 AQS ID

The AQS Site ID (State code, County code, and AQS Site ID) combined with the POC (Parameter Occurrence Code) used to uniquely define a monitor within the AQS database. The AQS ID appears in the top block of statistics as well as along the x-axis of the graph.

2.2.9 CV Upper Bound

The table column *CV Upper Bound* is the 90% confidence upper limit of the coefficient of variation of relative percent difference values for the [time period](#). An estimate of coefficient of variation upper bound is calculated for each monitor within a data group. The *CV Upper Bound* is calculated as follows:

$$CV = s_a * \sqrt{\frac{n}{\chi_{.1,n-1}}}$$

where n is number of relative percent difference values (the number of single point QC checks), s_a is the standard deviation of those n values (see s_a equation in section 2.2.10 below) and $\chi_{.1,n-1}$ is the 0.1 quantile of a chi-squared distribution (that is, the “lower critical value” of the distribution at probability= $1-\alpha=0.9$) with $n-1$ degrees of freedom. Values of CV are always positive and expressing in units of percent.

2.2.10 Bias and Sign Association

2.2.10.1 Absolute Bias

The column “*Bias*” is the 95% confidence upper limit on the mean of the absolute values of relative percent differences for the [time period](#). An estimate of absolute bias upper bound is calculated at the site level and monitor type group level. Absolute bias upper bound is calculated as follows:

$$|bias| = D_a + (t_{0.95,n-1} * s_a / \sqrt{n})$$

where D_a and s_a are the respective mean and standard deviation of the absolute values of the relative percent differences, calculated from a site’s or group’s n single-point QC checks as:

$$D_a = \frac{1}{n} \sum_{i=1}^n |d_i|$$
$$s_a = \sqrt{\frac{\left(n * \sum_{i=1}^n |d_i|^2 \right) - \left(\sum_{i=1}^n |d_i| \right)^2}{n * (n - 1)}}$$

The term $t_{0.95,n-1}$ in the $|bias|$ equation is the 95th quantile of a t-distribution (that is, the “upper critical value” of the distribution at probability= $\alpha=0.05$) with $n-1$ degrees of freedom. The value of $t_{0.95,n-1}$ is the 95th quantile of the “Student t” distribution table.

2.2.10.2 Sign Association for Absolute Bias

If the 25th and 75th percentile values of relative percent difference for a site or group have the same sign (either both being greater than 0 or both being less than zero), the absolute bias upper bound is given this sign (+ or -). If the 25th and 75th percentiles of relative percent difference have opposite signs, absolute bias has no sign association.

2.2.11 # Obs

The number of samples is the number of valued pairs of data used within the calculation. The number should be represented on the graphic with an “n”.

2.2.12 Quartiles (Q1, Q2, Q3)

The quartiles are the 25th, 50th, and 75th percentiles respectively. Each of these values is represented within the lines of the box on the box plot. The Q1 value is the lowest line on the box. The Q2 value is the line within the box and the Q3 value is the top line of the box.

2.2.13 Mean

The mean is the average value of the percent differences within the dataset.

$$Mean = \frac{1}{n} \times \sum_{i=1}^n \left(100 \times \frac{(ind_i - act_i)}{act_i} \right)$$

where “*d*” is the percent difference for a given observations, and “*n*” is the total number of observations within the dataset. The value of the mean is represented by a plus sign (+) on the box plot.

2.2.14 Whisker_{min} and Whisker_{max}

The Inter-Quartile Range (IQR) is defined as the difference between Q3 and Q1. The Whisker_{min} is defined as the smallest value that is greater than or equal to Q1 – (1.5*IQR). The Whisker_{max} is defined as the largest value that is less than or equal to Q3 + (1.5*IQR). The Whisker_{min} and Whisker_{max} values define the lengths of the “whiskers” that extend above and below the box. The ends of the whiskers are terminated with a horizontal line.

2.2.15 Outliers

Any value that is less than Q1 – (1.5*IQR) or any value that is greater than Q3 + (1.5*IQR) is defined as an outlier. All outliers are plotted on the graph. Outliers are represented by an asterisk (“*”).

2.2.16 95% CFR Upper / Lower Probability Limits

The CFR Upper / Lower Probability Limits give the 95% probability limits of relative percent difference values for the time period for a given data grouping. The probability limits are calculated as follows:

$$CFR\ Upper\ Probability\ Limit = D + (1.96 * s)$$

$$CFR\ Lower\ Probability\ Limit = D - (1.96 * s)$$

where D and s are the respective mean and standard deviation of relative percent differences for the data grouping.

The CFR Upper / Lower Probability Limits are shown only for reporting organizations that have more than 1 monitor within the data grouping.

2.2.17 Relative Percent Difference

The statistics are based on the relative percent difference values calculated from single point QC checks. Relative percent difference expresses the difference between the pollutant concentration indicated by monitoring equipment and the known concentration of the sample used in the check. The relative percent difference is calculated as:

$$d = 100 * \frac{(indicated - actual)}{actual}$$

where d is relative percent difference, indicated is the value obtained from the monitor, and actual is the known concentration level.